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Renewable Energy Targets and the Storage Cycling Trap

Unintended Effects and Implications for Power Sector Modeling

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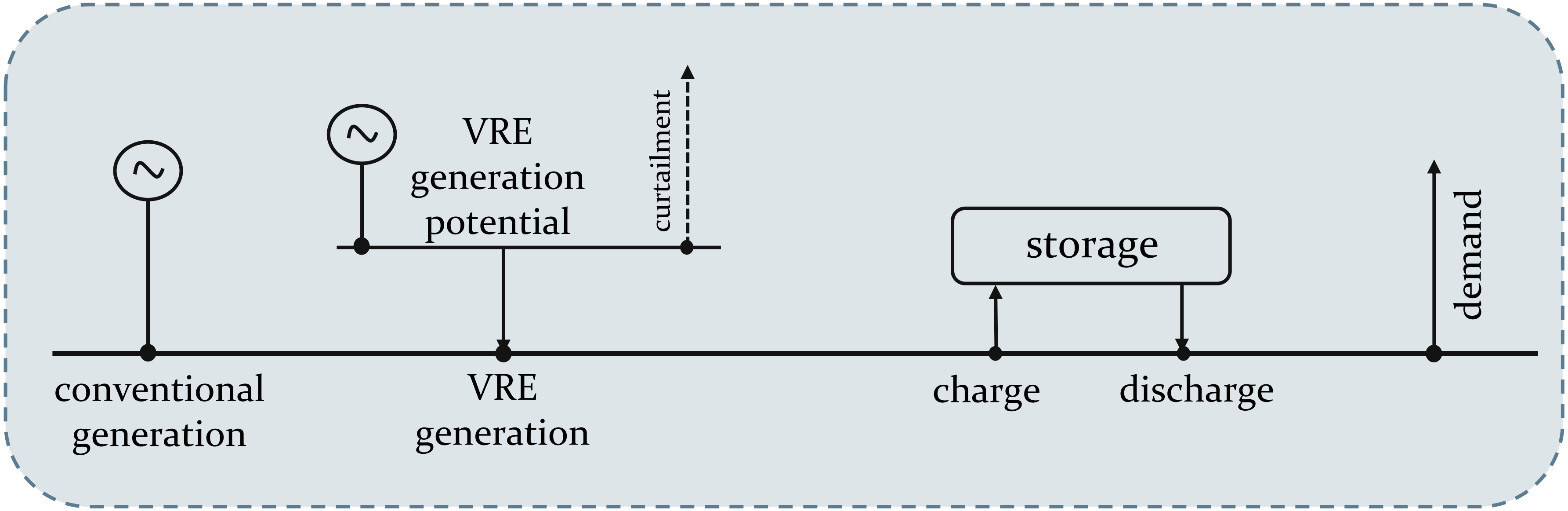
Berlin, April 9

Agenda

1. Problem setting
2. Research question
3. Methods
4. Key results
5. Conclusion

Simplified power sector



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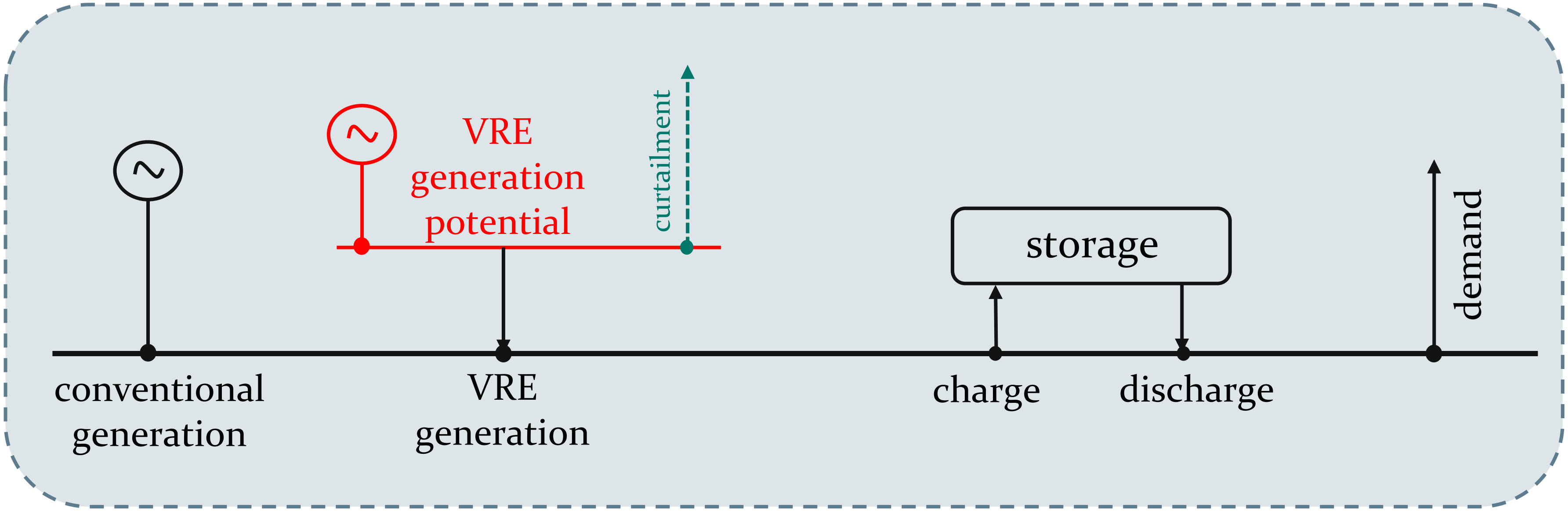
Expected outcome: some curtailment of renewable excess (or surplus) electricity (cp. Zerrahn et al. (2018))



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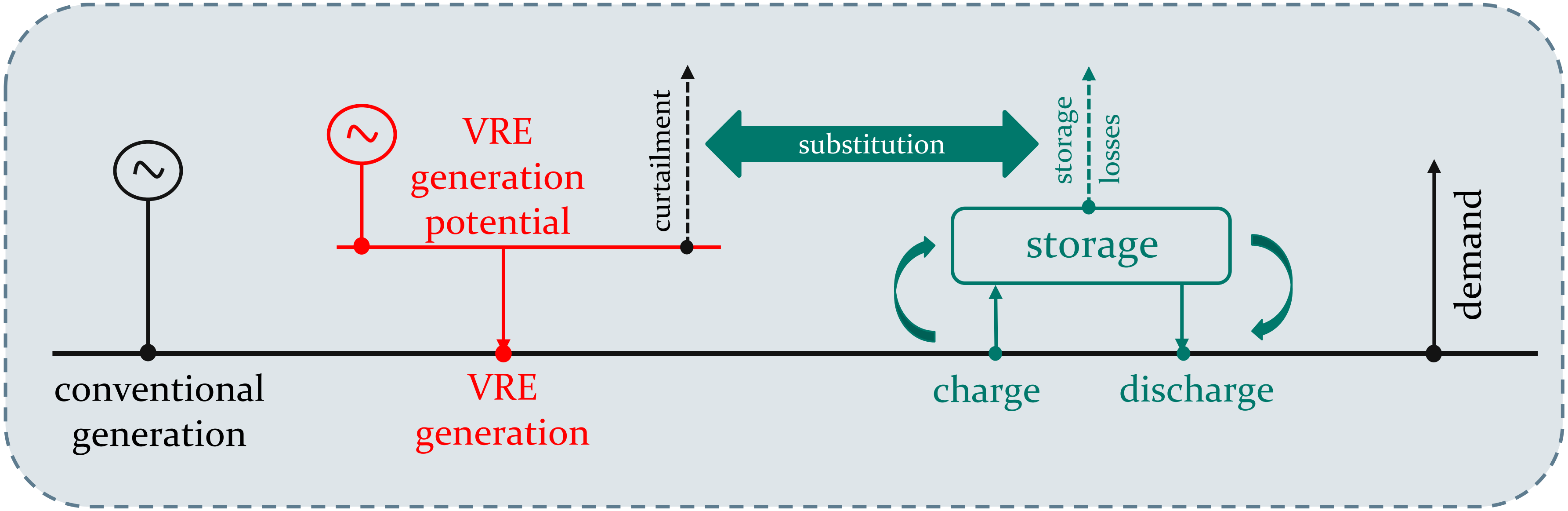
Imposition of minimum RES share ϕ causes unintended effects

$$\sum Generation^{RES} \geq \phi \sum Demand$$



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- Unintended storage cycling ≡ simultaneous, thus excessive, charging and discharging of the same storage unit

Research Questions

1. What are possible minimum RES share constraint formulations?
2. What is the effect of unintended storage cycling on model outcomes?
   - On storage: dispatch and investment
   - On remaining system elements: dispatch and investment, total system cost, prices
3. What are drivers of unintended storage cycling?
4. What are solution strategies?

Relevance

- RES targets commonly used in climate policy, e.g. in DE (65% in electricity sector by 2030) and USA (100% by 2035)
- Numerical models used for research & policy consulting → unintended storage cycling potentially distorts model outcomes, thus also policy recommendations

Model	renewable share in demand	conventional share in demand	renewable share in generation	conventional share in generation	consideration storage losses	CO_2 budget	CO_2 price
Calliope	x	x	x	x	partial	x	x
E2M2	x				complete	x	x
DIETER		x			complete	x	x
ENTIGRIS	x	x			no		x
LIMES-EU	x		x		partial	x	x
oemof	x	x			no	x	x
PyPSA	x		x		no	x	x
REMix	x		x		partial	x	x
EMMA	x				no		
anyMOD						x	x
dynELMOD						x	x
ELTRAMOD						x	x
ISAaR						x	x

Work in progress!

Source: own illustration

- Storage cycling has not yet been covered in literature*

*to the best of our knowledge

Methods: 12 implementation strategies

Investigated constraints

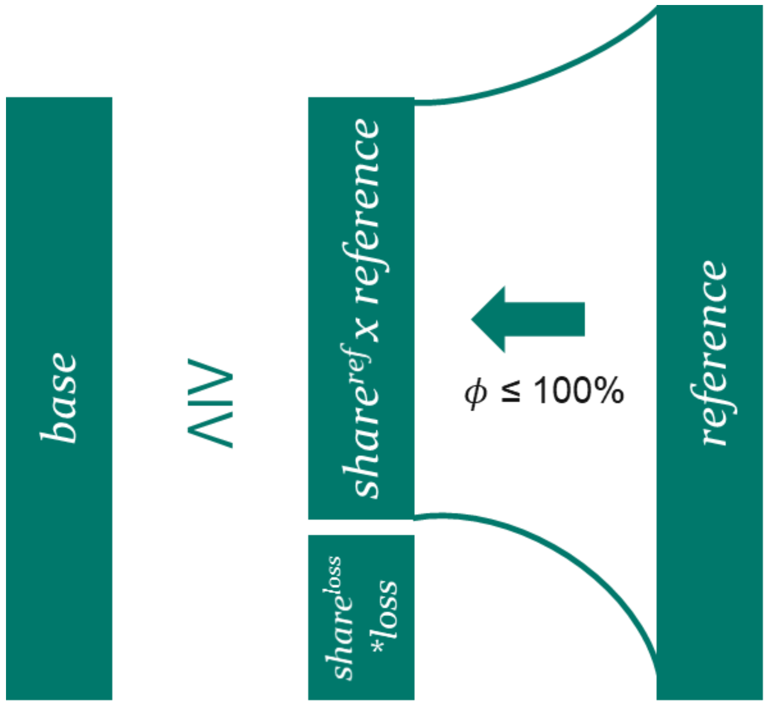
1. Minimum RES share in total demand
2. Minimum RES share in total generation
3. Maximum conventional share in total demand
4. Maximum conventional share in total generation

Variations per constraint

a) No SLCR: Storage losses covered by conventionals

b) Proportionate SLCR: Storage losses partially covered by RES and conventionals

c) Complete SLCR: Storage losses completely covered by RES



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Methods: numerical analysis

Stylized numerical power sector model → reduced DIETER (Zerrahn et al., 2017)

- Used in Zerrahn et al. (2018)
- Implemented in DIETERpy (Gaete et al., 2020)
- Linear, partial equilibrium model
- One region („copper-plate")
- 8760 h of target year
- Power sector only
- Annual demand = 504 TWh
- Minimum RES share $\phi = 80\%$

Input

Techno-economic parameters
- Conventional generators (coal, ocgt)
- RES generators (wind, pv)
- Storage (mid-term, comparable to pumped hydro)

Hourly time-series
- RES availability
- electricity demand

→

Model

Total system cost → MIN
- Annualized investment costs
- Fixed & variable costs

Subject to
- Electricity provision at all times
- Generation restrictions
- Storage restrictions
- Minimum RES share

→

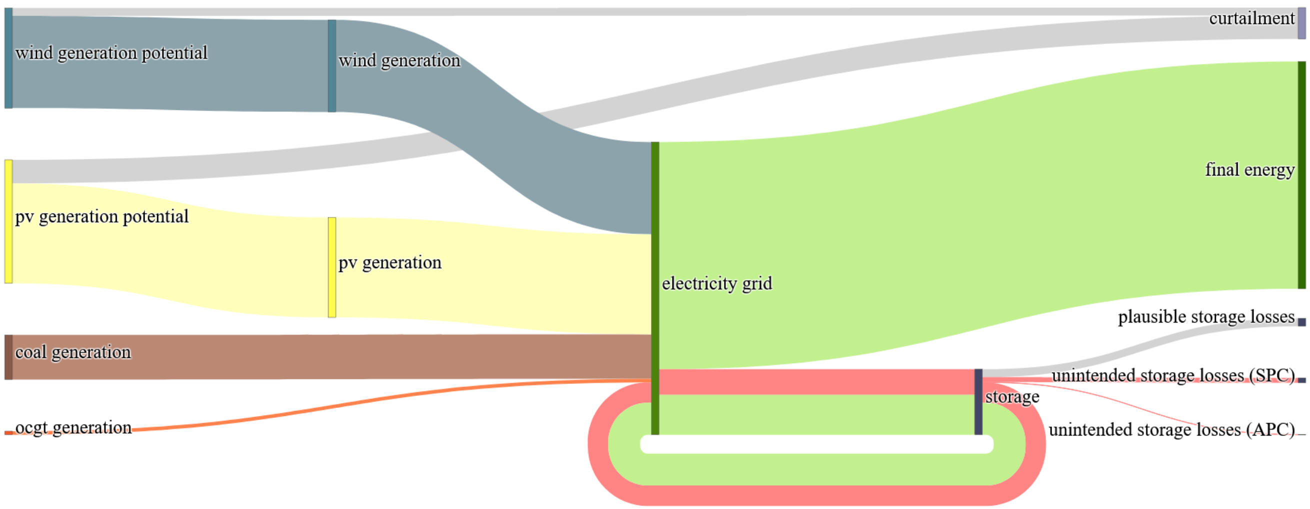
Output

Investment decisions (capacity)
- Conventional generators
- RES generators
- Storage

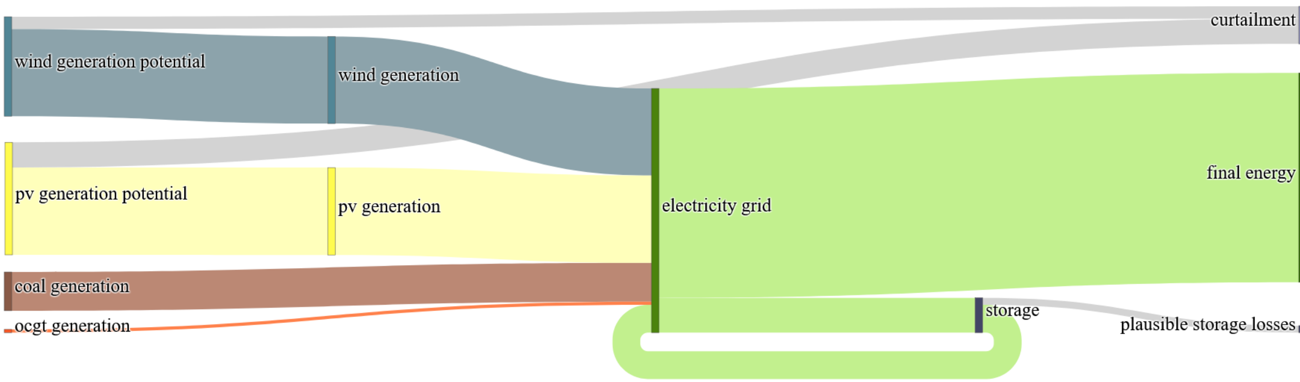
Hourly dispatch (energy)
- Conventionals
- RES
- Storages

Source: own illustration

Unintended storage cycling



No unintended storage cycling



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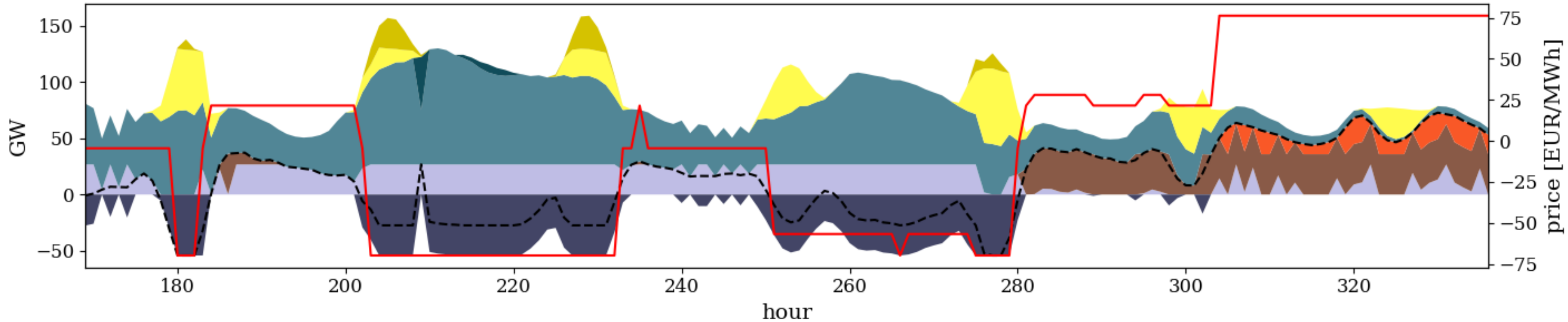
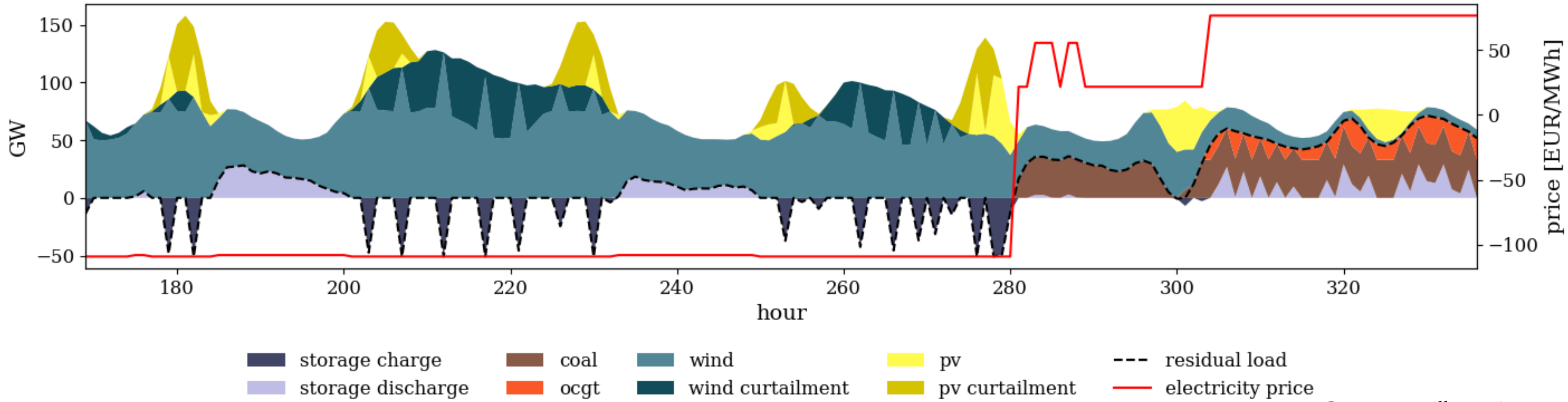
Unintended storage cycling



No unintended storage cycling



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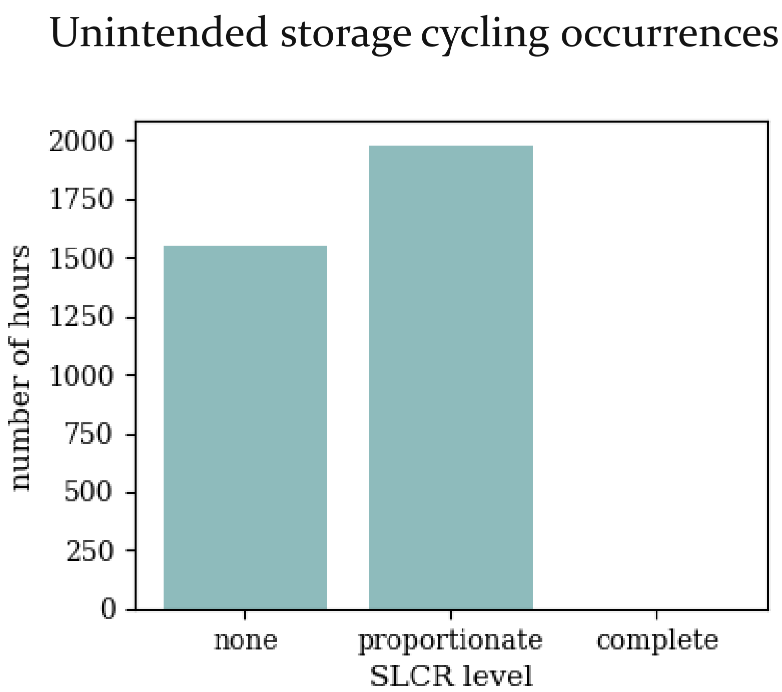
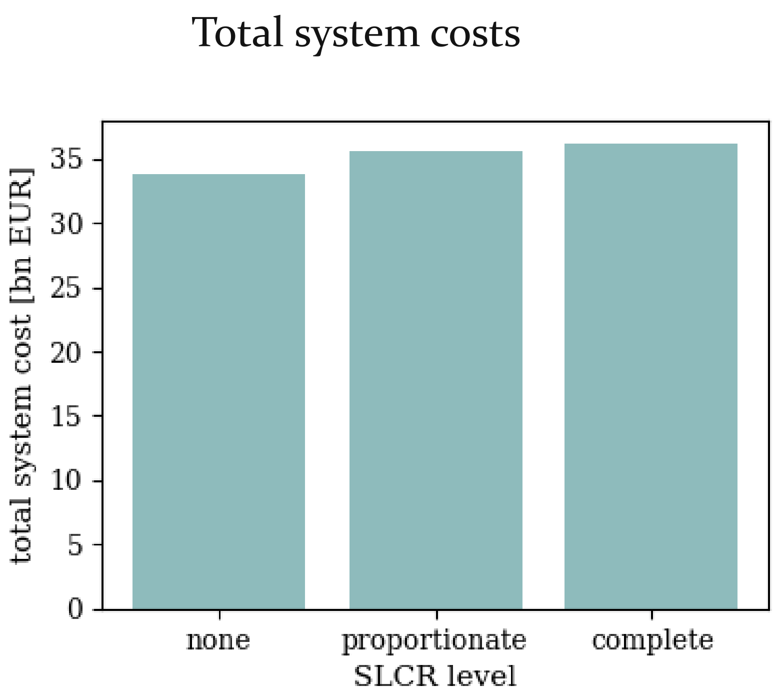
Unintended storage cycling – „medical report“



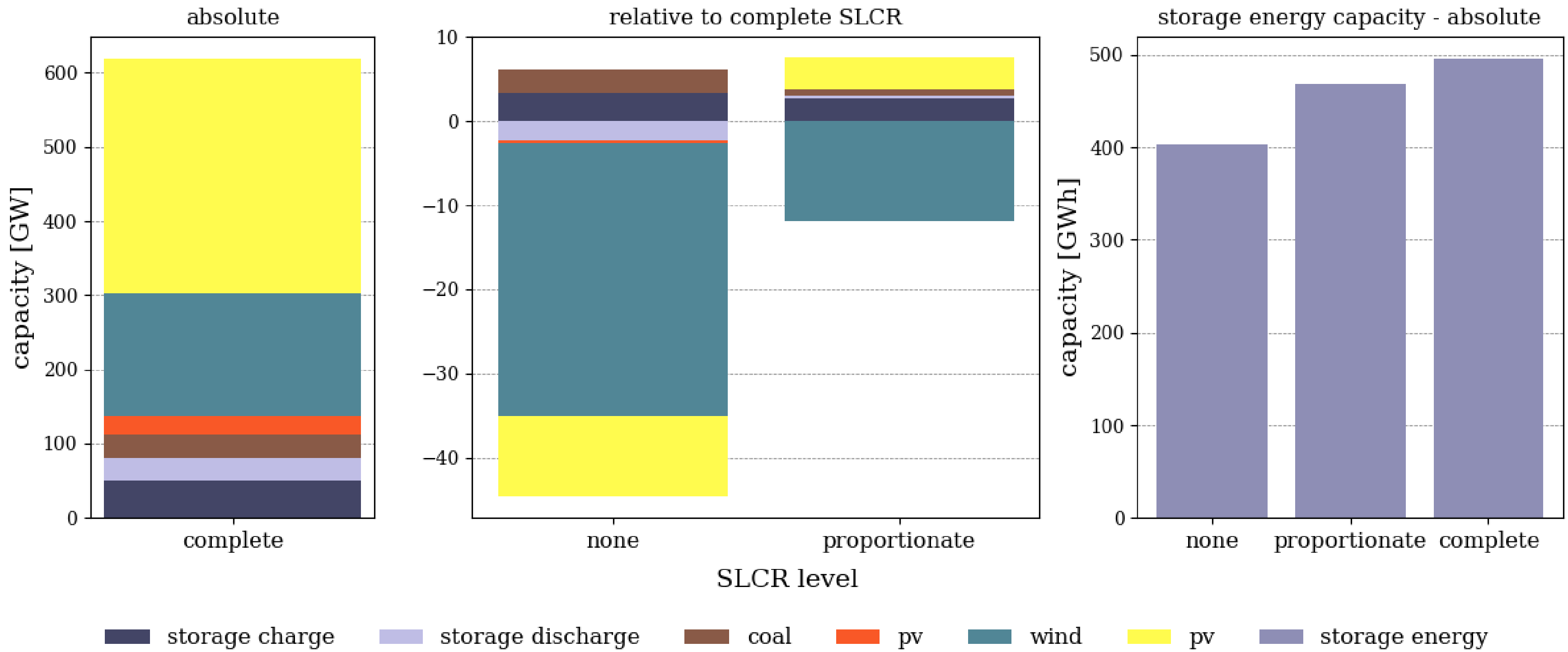


- SLCR: Storage Losses Covered by Renewables
- Models with complete SLCR by RES avoid unintended storage cycling

Source: own illustration

Impact on optimal investment decisions

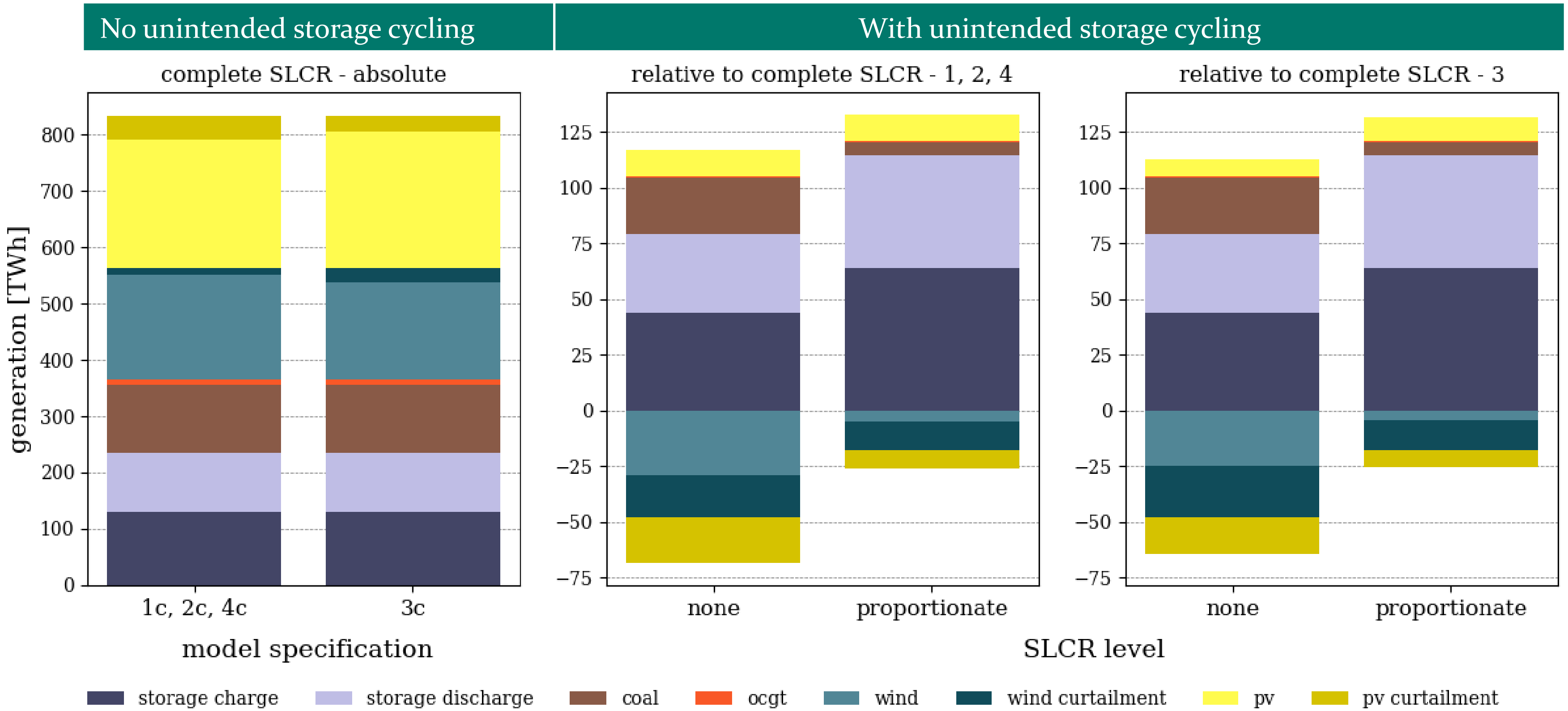
No unintended storage cycling	With unintended storage cycling	Storage energy capacity



SLCR: Storage Losses Covered by Renewables

Source: own illustration

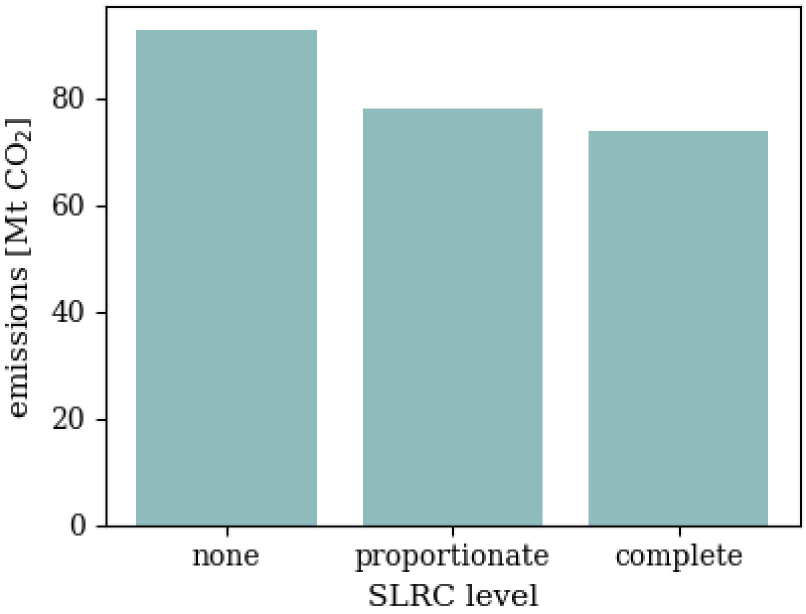
Impact on optimal dispatch decisions



SLCR: Storage Losses Covered by Renewables

Source: own illustration

Increased generation from coal → rise in emissions



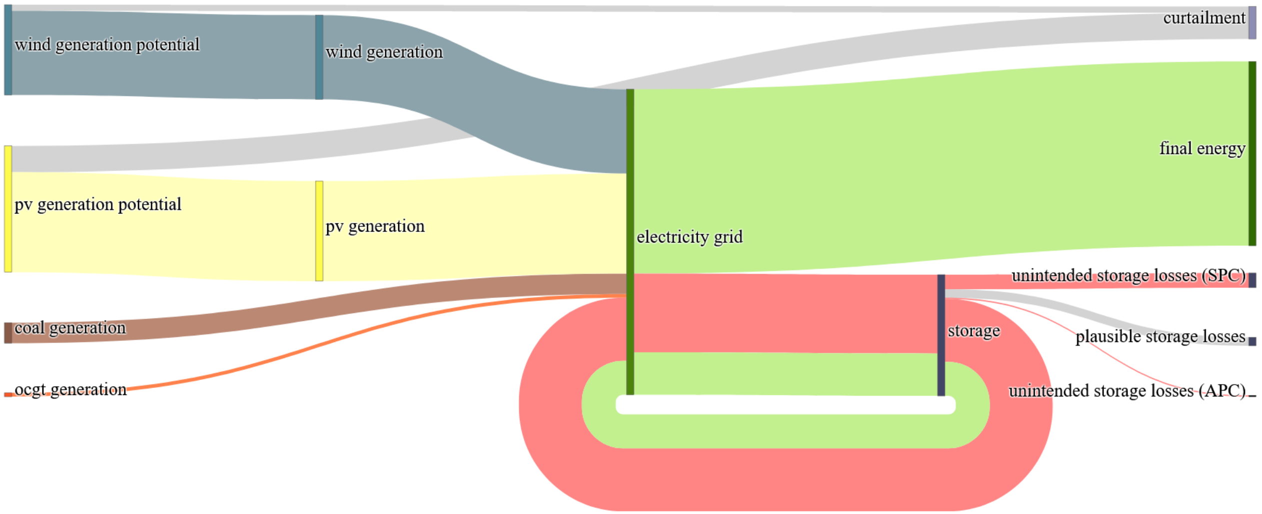
SLCR: Storage Losses Covered by Renewables

Source: own illustration

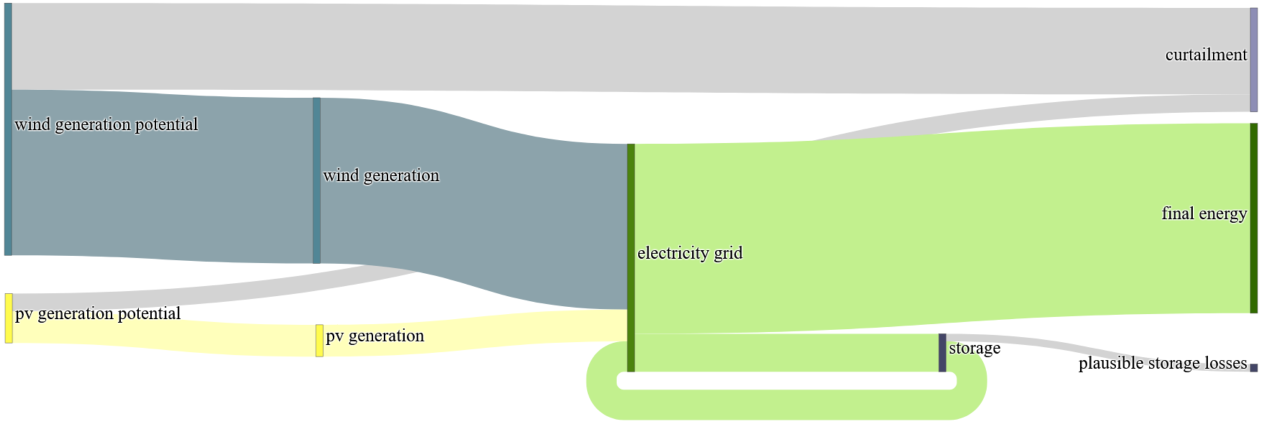
4.7

Energy flows in a fully renewable system

Unintended storage cycling



No unintended storage cycling



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5.1

Conclusion

Solution strategies

- Complete coverage of storage losses by RES prevents unintended storage cycling
- Possible alternatives
  - Theoretical RES generation potential → imprecise, underachievement
  - CO_2 budget, CO_2 price

  → binding RES policy targets cannot be modeled

Summary

- Unintended storage cycling has significant effect on model outcomes → distortion of policy recommendation
- Implementation matters → complete storage losses in RES constraint is a necessity for cost-optimal decarbonization pathways

References

Zerrahn, Alexander, and Wolf-Peter Schill. "Long-run power storage requirements for high shares of renewables: review and a new model." *Renewable and Sustainable Energy Reviews 79* (2017): 1518-1534.

Zerrahn, Alexander, Wolf-Peter Schill, and Claudia Kemfert. "On the economics of electrical storage for variable renewable energy sources." *European Economic Review 108* (2018): 259-279.

Gaete-Morales, C., Kittel, M., Roth, A., Schill, W. P., & Zerrahn, A. (2020). DIETERpy: a Python framework for The Dispatch and Investment Evaluation Tool with Endogenous Renewables. *arXiv preprint arXiv:2010.00883.*

Source: own illustration

Thank you for your attention!

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